Multi-model assessment of the late-winter ENSO teleconnection in the Euro-Atlantic sector

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OBJECTIVE: atmosphere-only simulations are used to investigate the ENSO teleconnection in the North-Atlantic European region (NAE) in late winter (JFM).

1. Experimental set-up

CTL: control experiment with prescribed climatological Sea Surface Temperature (SST) from HadISST (1981-2010);
EN: sensitivity experiment with SST anomalies of a canonical El Niño event superimposed on the seasonal cycle;
LN: same as EN, but with flipped-sign anomalies.

- 1-year integrations × 50 members

This set of experiments is run using 3 state-of-the-art models:

- **EC-EARTH3.2** (T255L91, 0.01hPa)
- **ARPEGE6.3** (T127L91, 0.01hPa)
- **CAM5.2** (1°×1°,L46, 0.3hPa)

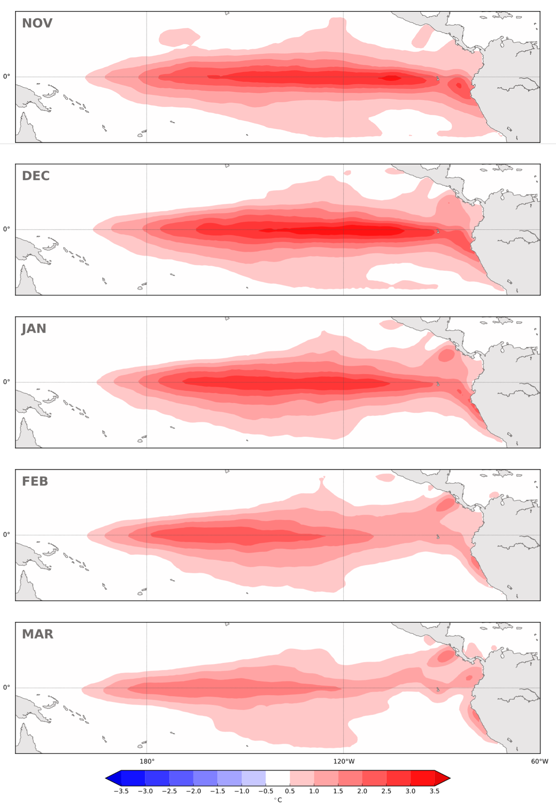


Figure 1. Monthly means of the superimposed SST anomalies in EN from Nov to Mar.

2. ENSO-Forced Tropical Convection and Divergence

- 200-hPa velocity potential and divergent wind anomalies indicate an eastward shift in the **equatorial divergence** in EN, consistent with the shift in tropical precipitation and the associated diabatic heating.
This shift is common to all models, but weaker in CAM.

- Changes in upper-level divergence are much weaker in LN and represent a suppression of **tropical convection**. The anomalies are located west of the date line, in contrast to EN (east of date line). As for EN, ARPEGE shows the strongest signal.

- Regardless the amplitude of the tropical response, the **extra-tropical teleconnection** is similar in all models: the wave train has the same structure and magnitude. There is a clear westward shift in LN as compared to EN, which is not that much apparent in the tropics.

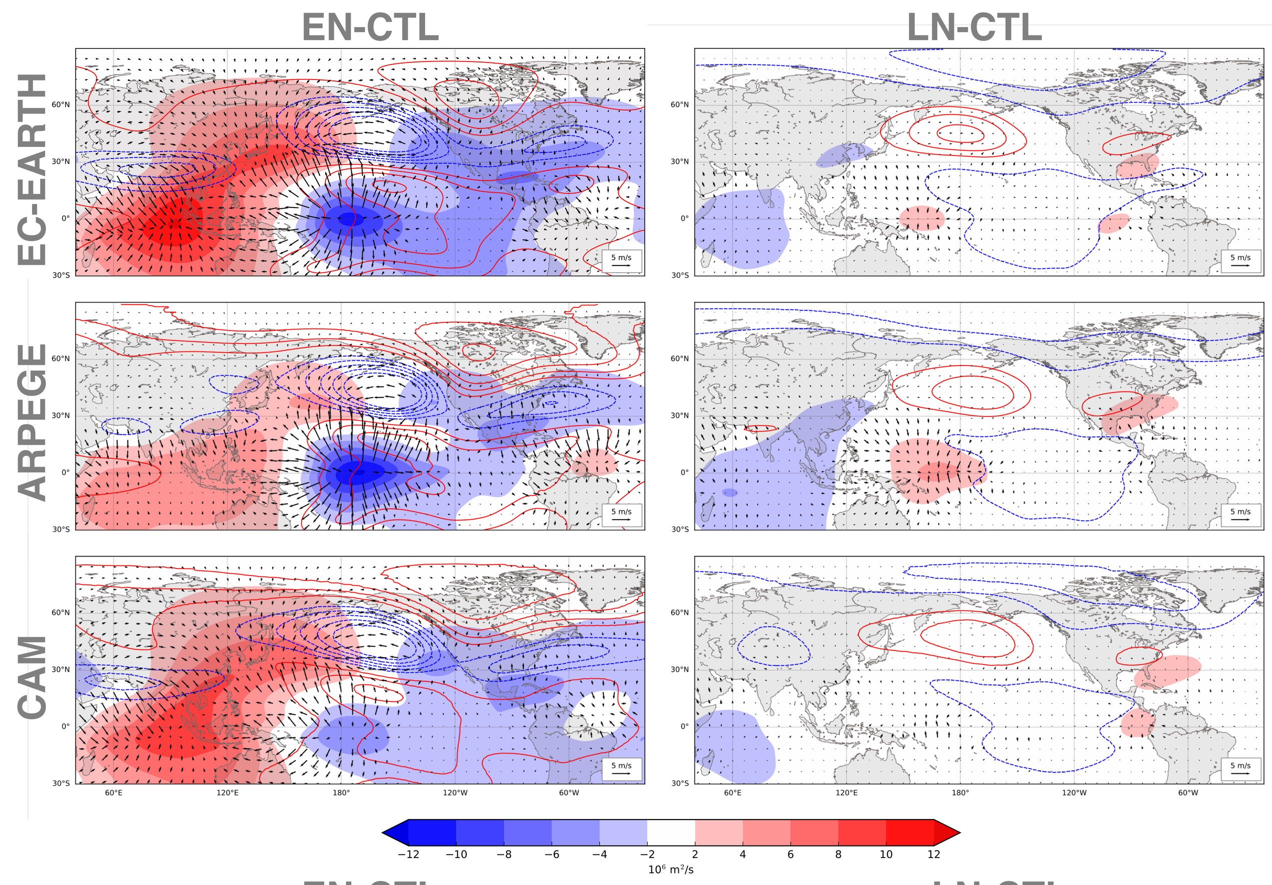


Figure 2. Divergent wind (arrows), velocity potential (shading) and Z200 (contours) anomalies in EN and LN with respect to CTL, for the three models.
Contour interval: 30 hPa.

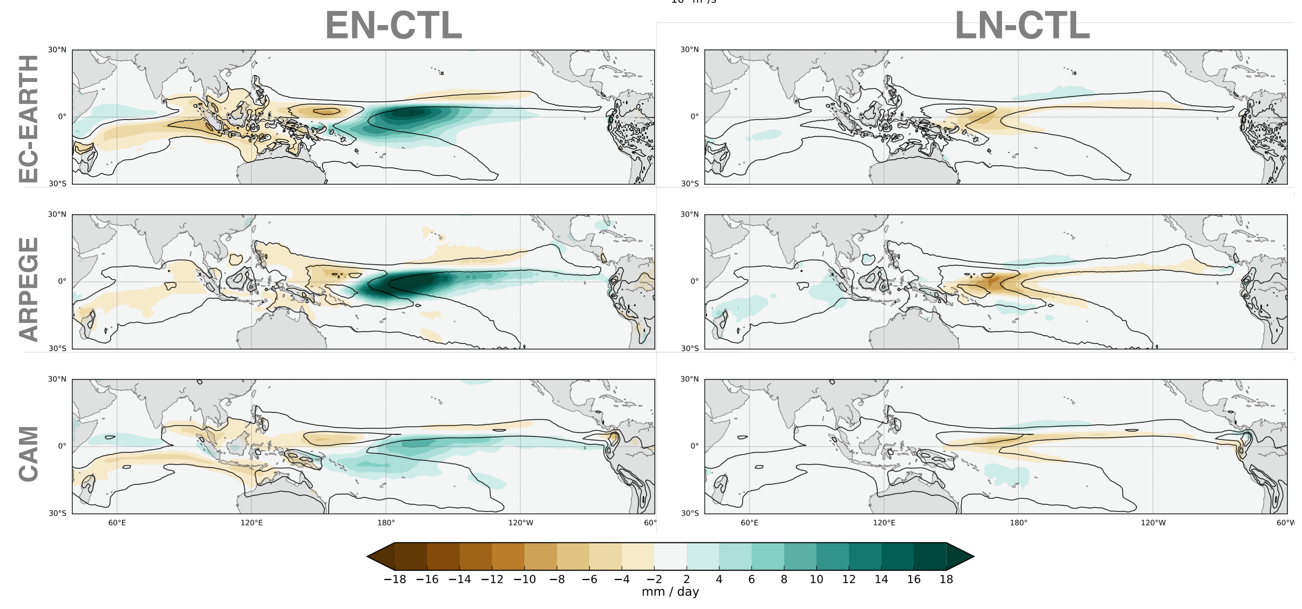
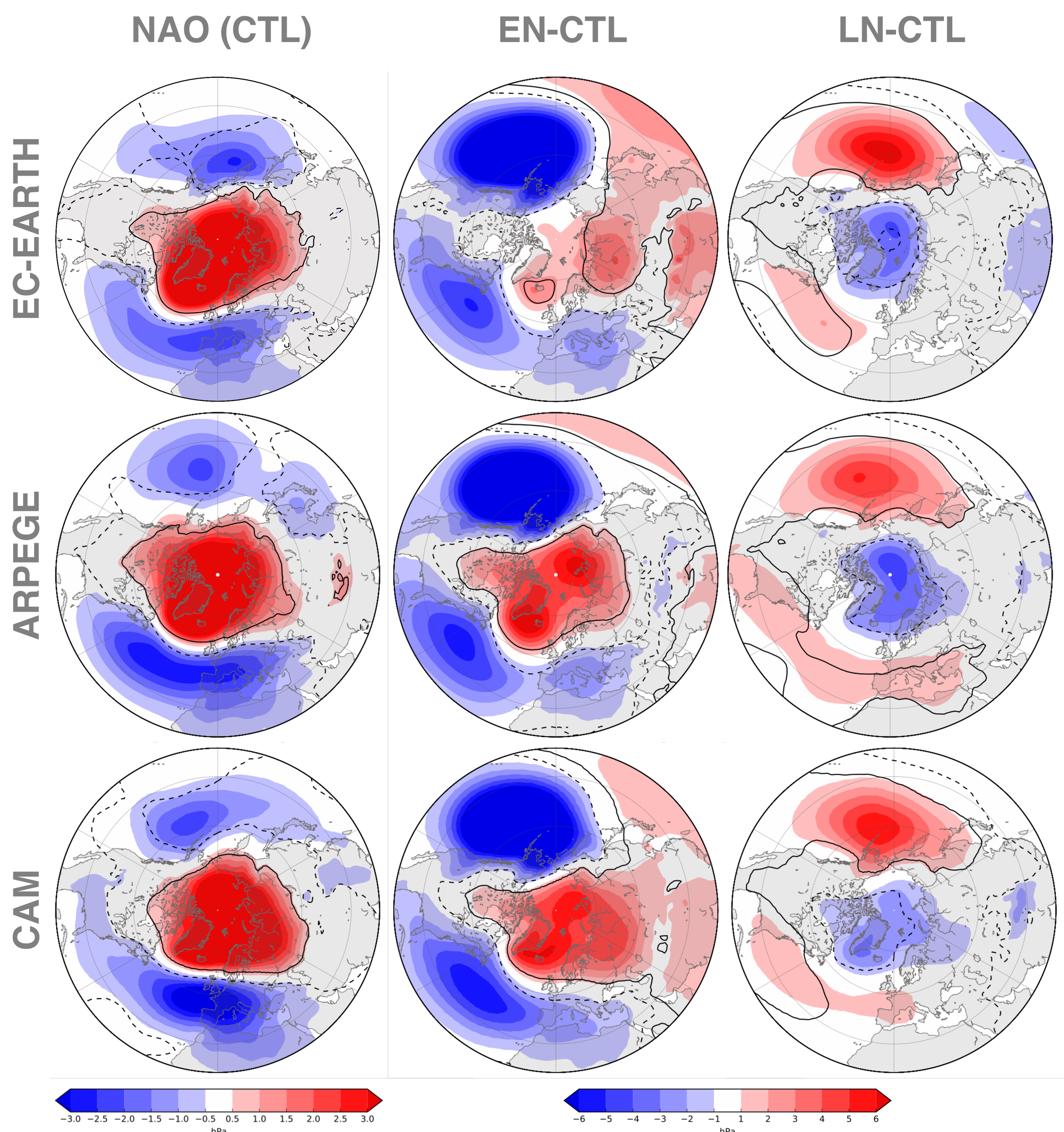


Figure 3. Precipitation anomalies (shading) in EN and LN with respect to CTL for the three models, with respective CTL climatology (contours).
Contour interval: 5 mm/day.

3. ENSO-NAE Teleconnection vs. NAO: Sea-Level Pressure



- The atmospheric **internal variability** is examined in CTL.

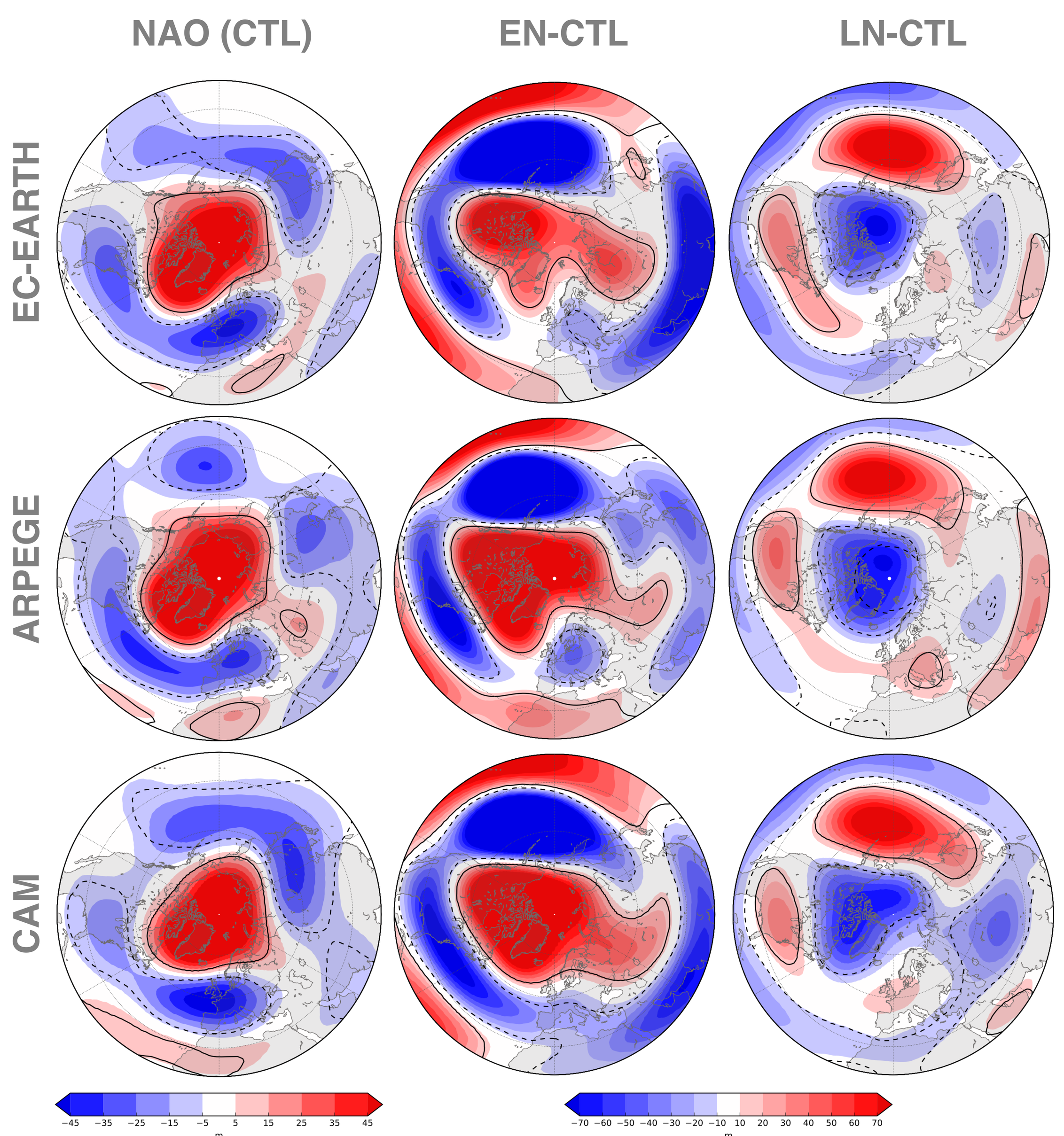
The NAO⁻ typical **dipolar signature** in Sea-Level Pressure (SLP) emerges as the 1st EOF over the NAE domain (20°N-90°N; 90°W-40°E), with model diversity in the location of the centres of action.

- The **forced response** in EN and LN is evaluated as the difference from CTL.

The strongest response is in the North Pacific (Aleutian Low), but weaker and shifted westward in LN. In the **North Atlantic**, a dipole similar to the NAO pattern is present, but the mid–latitude anomalies are centred west of the NAO ones. Again, LN shows a weaker response.

Figure 4. *Left:* regression of SLP anomalies on the NAO-index in CTL, for the three models. *Middle and right:* SLP anomalies in EN and LN with respect to CTL, for the three models. Contours indicate 95% significance.

4. ENSO-NAE Teleconnection vs. NAO: Upper Troposphere (Z200)



- The NAO upper-level signature (geopotential height at 200 hPa) is evaluated with linear regressions on the EOF-based NAO-index.

Anomalies projecting on the **circumglobal waveguide** pattern appear in the three models.

- The ENSO upper-tropospheric response is also examined.

The tropospheric Rossby **wave train** is present in both EN and LN, roughly symmetric in sign but with a different arching pathway (see *Section 2*) and amplitude (as in SLP; see *Section 3*).

Figure 5. *Left:* regression of Z200 anomalies on the NAO-index in CTL, for the three models. *Middle and right:* Z200 anomalies in EN and LN with respect to CTL, for the three models. Contours indicate 95% significance.

5. ENSO-NAE Teleconnection vs. NAO: Precipitation and EKE

The Eddy Kinetic Energy (EKE) at 200 hPa is computed from daily data with a 24-h filter to investigate the role of **transient eddies**, and compared with anomalous precipitation.

- The linear regressions on the NAO-index in CTL indicate a southward shift of the North Atlantic storm-tracks, which leads to the characteristic **wet-dry dipole** over Europe.

- EN mainly affects the **storm-track**s in the North Pacific, and consequently precipitation over North America.
Some impacts are found in the eastern North Atlantic, hardly reaching Europe.

- In agreement with the smaller changes in the atmospheric circulation (SLP,Z200), LN shows little impact, particularly in the NAE region.

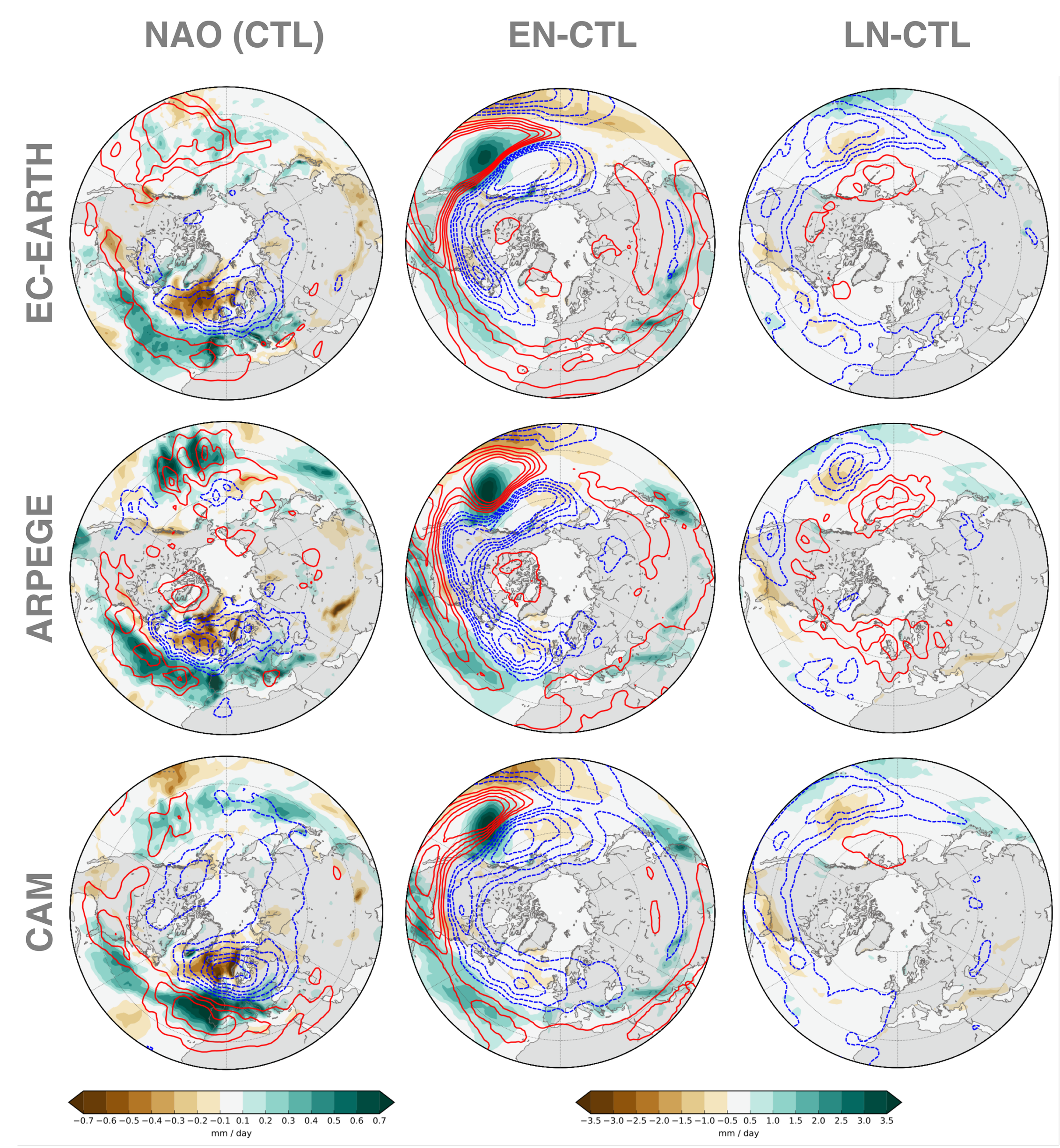


Figure 6.
Left: regression of precipitation (shading) and EKE (contours) anomalies on the NAO-index in CTL, for the three models (EKE at 200 hPa in EC-EARTH and CAM; 300 hPa in ARPEGE). Contour interval: 5 m^2/s^2.
Middle and right: precipitation (shading) and EKE (contours) anomalies in EN and LN with respect to CTL, for the three models. Contour interval: 10 m^2/s^2.

Key Messages

- **The late-winter ENSO teleconnection in the NAE is dynamically distinct from the NAO. Considering the upper levels is fundamental to diagnose the different dynamics involved.**
- **The extra-tropical ENSO wave train is robustly simulated in all models, with a similar amplitude and structure regardless the tropical response.**
- **There is a clear sensitivity of the extra-tropical ENSO response to EN versus LN (longitudinal shift), which is not present in observations, long-term reanalyses and AMIP simulations. It is not clear whether this sensitivity is related to the unrealistic LN forcing or to an actual non-linearity of the atmospheric response.**

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